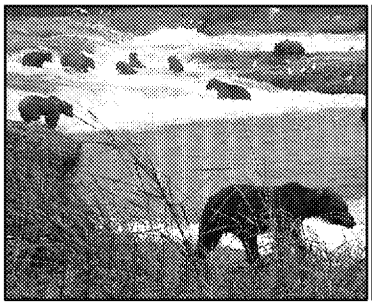
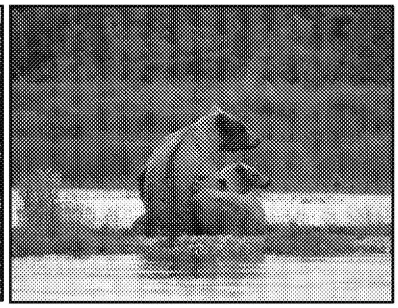
Brown Bears and the Pebble Project in Southwest Alaska

By

Lowell H. Suring
Principal Wildlife Ecologist
Northern Ecologic L.L.C.
10685 County Road A
Suring, Wisconsin 54174

Prepared for the Friends of McNeil River





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Cover photographs: Left – Brown bears at McNeil River Falls in July (Photograph from Wikimedia Commons by DrewHH). Center – Viewing brown bears at Chinitna Bay in Lake Clark National Park and Preserve (Photograph from the National Park Service by J. Pfeiffenberger). Right – Brown bear sow with cubs at Katmai National Park and Preserve (Photograph from the National Park Service).

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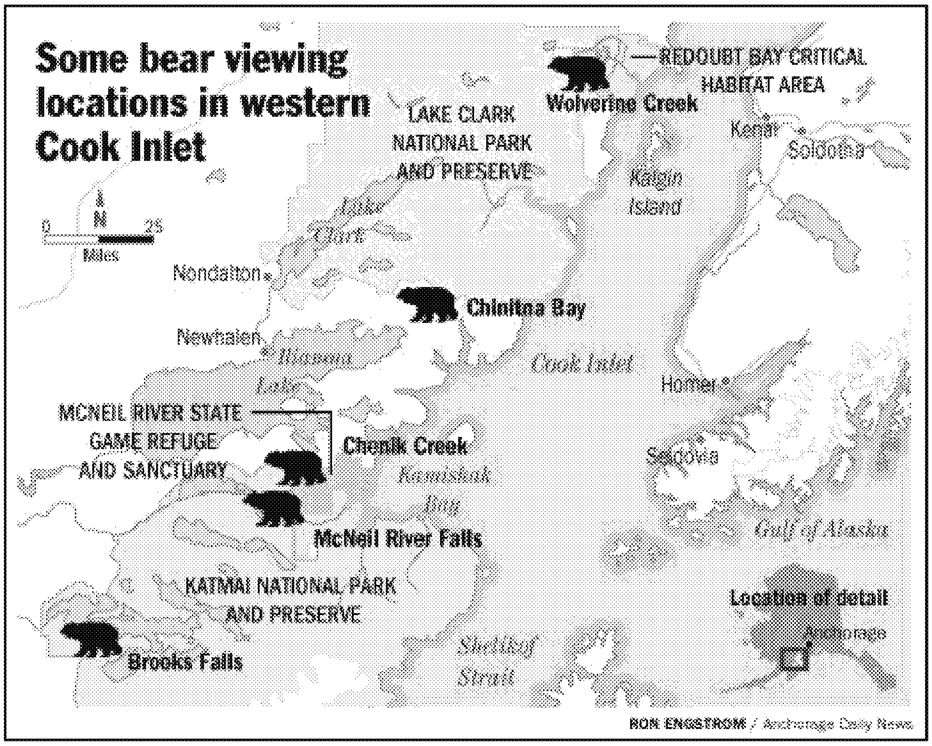
Brown Bears and the Pebble Project in Southwest Alaska[1]

Lowell H. Suring, Northern Ecologic L.L.C., 10685 County Road A, Suring, Wisconsin 54174, USA

Executive Summary

Introduction

Much of the wildlife viewing activity in Southwest Alaska is centered on observing brown bears (*Ursus arctos*). Katmai National Park and Preserve is becoming best known for opportunities to observe brown bears that congregate at Brooks Falls. Chinitna Bay, Crescent Lake, and Silver Salmon Creek offer opportunities in Lake Clark National Park and Preserve for world class viewing of brown bears.



McNeil River supports the world's largest congregation of brown bears. Recognizing this, the Alaska State Legislature established the McNeil River State Game Sanctuary, the McNeil River State Game Refuge (Refuge), and the Kamishak Special Use Area to provide permanent protection for brown bears and opportunities for wildlife viewing (among other uses). Southwest Alaska residents and visitors were estimated to spend nearly $145,000,000 (2019 dollars) annually to view wildlife and generated more than an additional $133,000,000 in associated annual economic activity.

[1] This document is an update and revision of Suring (2019).

The Pebble Limited Partnership is proposing to develop the Pebble copper-gold-molybdenum porphyry deposit as a surface mine in Southwest Alaska. In 2017, applications were submitted to the U.S. Army Corps of Engineers for development of the Pebble Mine (Project); including one alternative that would place a road and a natural gas pipeline closer than 76 – 91 m (250 – 300 ft) and an industrial port facility within 3.2 km (2 mi), respectively, of the northern border of the Refuge. This document reviews the potential impacts on brown bears of the proposed roads, natural gas pipelines, and road corridors from the mine site to the port facilities accessing Cook Inlet and the port facilities themselves.

Issues

Comments from the public during the scoping process for the Project included concern regarding wildlife, with specific emphasis on brown bears including the effects of noise, potential for brown bear mortality due to defense of life or property (DLP), and food-conditioning of brown bears. Other identified issues included the effects of the Project on brown bear denning behavior and habitat, and the effect of Project roads on brown bear behavior and habitat. Additionally, there are issues with the overall analysis of impact in the Final Environmental Impact Statement (FEIS), discussion of cumulative effects, presentation of mitigation practices, and adequacy of base-line studies.

- The FEIS provides very little evaluation of the potential impact of noise generated by the project on brown bears. This needs to be better addressed to evaluate the potential effects of noise generated by the Project on brown bears (e.g., disturbance of denning brown bears) and to provide a basis for mitigating those effects.

- Food-conditioned brown bears are likely to occur with implementation of the Project. As a result, these brown bears will have increased vulnerability to mortality through DLP kills. To mitigate the potential of human-brown bear encounters, roads developed for this project should avoid high quality habitats for brown bears. Additional mitigation measures relative to use of project roads should follow those implemented for the Greens Creek Mine in Southeast Alaska.

- The most direct and most effective approach to dealing with food-conditioned brown bears is to have agency personnel kill them. To avoid these situations, it will be necessary to have in-depth training on food-handling for all Project personnel so they understand and appreciate the seriousness of preventing food-conditioning in brown bears.

- Discussion of brown bear den sites within the area that may be affected by the Project was limited to a description of the findings of an aerial survey of den locations. The potential for increased human activities in this area as a result of resource extraction and human access associated with the Project requires a fuller understanding of specific denning requirements of these brown bears. This information will be essential for assessing the impact of the Project on denning brown bears and developing future management actions that do not jeopardize the brown bear population.

- Management of human access associated with roads will help to reduce mortalities of brown bears in proximity to roads. However, this will not address mortalities of brown bears resulting from collisions with Project vehicles on the road or the fragmentation of habitat due to the reluctance of brown bears to cross or approach the road when it is in service. To maintain movement patterns of brown bears in the area, it will be necessary to describe movement corridors for brown bears, identify probable locations for brown bears to cross the road, and facilitate crossing activity.

- Analysis of impacts is the technical heart of a FEIS. Generally, there was not an analysis of the impact of the issues related to brown bears in the Project's FEIS that completely addressed the factors of analysis the Project's FEIS used to evaluate environmental consequences (i.e., magnitude or intensity, duration, geographic extent, potential to occur). This was despite assurances in the FEIS that such an analysis would be completed.

  Magnitude or *intensity* of the potential effects associated with these issues was not addressed for brown bears. This would have provided insight to the potential risk of implementing the Project to brown bears. Magnitude of effect would be best described for brown bears as estimated changes in distribution, population density, and demographic factors. None of those were specifically addressed.

  Duration of the effect of most issues was generally adequately addressed (i.e., the effect would last the life of the Project).

  Analysis of the *Geographic extent* of the effect was problematic in that brown bears are a landscape species and the analysis area for analyzing effects on terrestrial mammals (including brown bears) resulting from actions within the transportation corridors and at the ports was limited to a 4.8-km (3-mi) radius.

  The FEIS also did not provide an analysis of the *likelihood* of recognized impacts on brown bears occurring if the Project were to be permitted and implemented and does not evaluate the *probability* of occurrence of recognized impacts based on results of analysis or modeling. These analyses would also help to establish the degree of risk to brown bear populations upon implementation of the Project.

- A comprehensive analysis of the cumulative effects on brown bears would certainly include the combination of changes to the brown bears' environment that are caused by Project actions in combination with other past, present, and potential future human actions. The discussion of cumulative effects in the FEIS does not specifically address brown bears. The potential effects identified in this discussion also were not analyzed relative to the influence they may have on brown bear populations. A more in-depth analysis is needed that evaluates changes in quality of habitat for brown bears as a result of habitat modification and the reduction in the effectiveness of that habitat as a result of disturbance and mortality.

- The risk of mortality to brown bears and ecological disruption associated with the Project area is high. An integral part of managing the Project will be the development and full implementation of a comprehensive mitigation plan. Mitigation planning will provide the means and opportunity to integrate conservation of ecological processes into the design and implementation of the Project to reduce that risk. Therefore, it is critical that the complete mitigation plan be available to the public for review and evaluation prior to approval of the Project.

- Base-line studies for brown bears should include a more comprehensive synthesis of the relevant literature, periodic population estimates within the Project area, determination of landscape-use patterns, and use of those data to conduct analyses of habitat use in the project area.

Conclusions

Brown bears associated with the Project area are a resource that has high ecological, economic, and social value. Any impact on this resource through implementation of a large-scale mining project will have significant ramifications. The data and analysis provided in the Affected Environment and the Environmental Consequences sections of the FEIS are not adequate to fully understand and evaluate the effects of potential management alternatives on brown bear habitat and populations in this area.

In-depth analyses and evaluation of the ecological relationships of brown bears in the Project area are needed to provide information for conservation and management of these animals. Wildlife corridors and mitigation passages are critical to the conservation of brown bears in this area, especially in ensuring that landscape use patterns of brown bears are maintained. Also, upon initiation of the Project, a rigorous monitoring plan needs to be implemented to evaluate the accuracy of effects analyses and the effectiveness of the mitigation strategy to ensure the continued wellbeing and likely survival of these brown bears.

Introduction

Much of the wildlife viewing activity in Southwest Alaska is centered on observing brown bears (*Ursus arctos*) (Matt and Suring 2018). Based in part on a capture-mark-resight estimate of brown bear density on the Katmai Coast (Miller et al. 1997), Sellers (2001) estimated that 2,000–2,500 brown bears inhabit federal and state managed lands on the upper Alaska Peninsula (including Lake Clark National Park and Preserve, Katmai National Park and Preserve, McNeil River State Game Sanctuary, and McNeil River State Game Refuge).

Lake Clark National Park and Preserve

Lake Clark National Park and Preserve in Southwest Alaska, about 160 km (100 mi) Southwest of Anchorage was first proclaimed a national monument in 1978, then established as a national park and preserve in 1980 by the Alaska National Interest Lands Conservation Act (Figure 1). The park includes many streams and lakes vital to the Bristol Bay salmon fishery, including its namesake, Lake Clark. Chinitna Bay, Crescent Lake, and Silver Salmon Creek offer opportunities in the National Park and Preserve for world class viewing of brown bears (https://www.nps.gov/lacl/planyourvisit/bear-viewing.htm; accessed 30 May 2020).

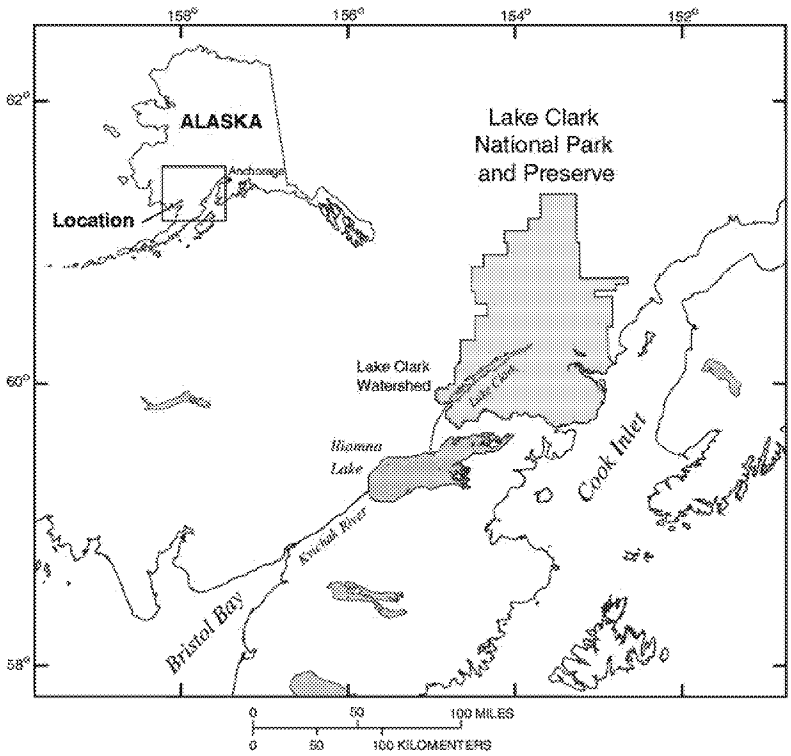


Figure 1. Lake Clark National Park and Preserve in Southwest Alaska (from Brabets and Ourso 2006).

Unique concentrations of food for brown bears at Chinitna Bay promote high numbers of brown bears foraging on protein-rich sedges, clams, and salmon. Park biologists have counted as many as 219 brown bears within a 140 km^2 (54 mi^2) area on the coast (NPS 2015). From 2010 to 2019 visitor use increased from approximately 4,000 days to over 19,000 days (NPS 2020). Most of this increase has been on the Cook Inlet (coastal) side of the park. In 2019, Crescent Lake, Silver Salmon Creek, and Chinitna Bay were the most highly visited places in the Park, together accounting for over 70% of visitation (over 13,000 days combined). Crescent Lake has seen a large growth in visitor use, increasing from over 1,600 reported visitor use days in 2010 to almost 5,000 in 2019. The number of visitor use days that included viewing of brown bears as the main activity has risen from approximately 1,000 people in 2007 to about 8,000 in 2018.

Katmai National Park and Preserve

Katmai National Park and Preserve is located on the Alaska Peninsula, across from Kodiak Island, about 470 km (290 mi) southwest of Anchorage (Figure 2). The area was first designated a national monument in 1918 to protect the area around the major 1912 volcanic eruption of Novarupta, which formed the Valley of Ten Thousand Smokes. Initially designated because of its volcanic history, the monument became appreciated for the wide variety of wildlife, including an abundance of sockeye salmon (*Oncorhynchus nerka*) and the brown bears that feed upon them. After a series of boundary expansions, the present national park and preserve were established in 1980 under the Alaska National Interest Lands Conservation Act.

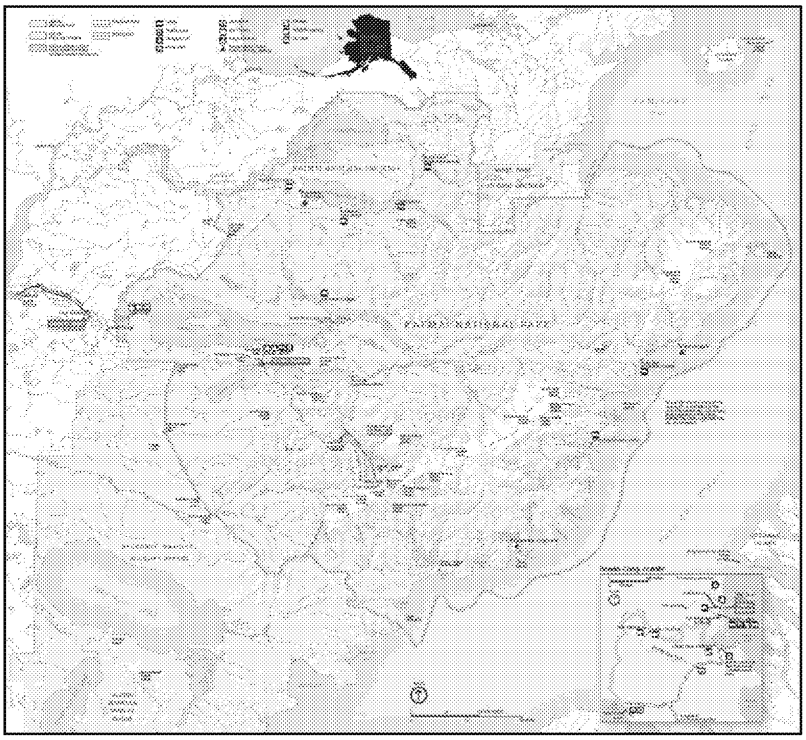


Figure 2. Katmai National Park and Preserve in Southwest Alaska (from National Park Service).

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Katmai National Park and Preserve has the highest documented density of brown bears in North America (Sellers et al. 1999). It is becoming best known for opportunities to observe brown bears that congregate at Brooks Falls for the salmon run (Fay and Christensen 2012). At Brooks Camp, a substantial salmon run supports large concentrations of brown bears, especially in July when the fish are migrating upriver, and in September when spawned out salmon are abundant. National Park Service personnel have recorded 40–>60 brown bears fishing along the 1.6 km (1 mi) Brooks River (Olson and Putera 2007). From 2010 to 2019 visitor use has fluctuated between 25,000 and 37,000 per year (NPS 2020). The 3 main activities reported by commercial operators in Katmai National Park and Preserve were sport fishing, viewing brown bears, and air taxi; however, these activities are not mutually exclusive. The annual variation in visitation to Katmai could be due to changes in the timing and magnitude of salmon runs that, in turn, may affect fishing and brown bear viewing opportunities.

McNeil River

McNeil River (Figure 3) supports the world's largest congregation of brown bears (Griffin and Weiss 2020). In 2018 16–77 individual brown bears were observed per day at McNeil River Falls throughout July. The Alaska State Legislature established the McNeil River State Game Sanctuary (Sanctuary) in 1967 to:

1. provide permanent protection for brown bears and other fish and wildlife populations and their habitats so that these resources may be preserved for scientific, aesthetic, and educational purposes;

2. manage human use and activities in a way that is compatible with the permanent protection of brown bears and enhance the unique brown bear-viewing opportunities within the Sanctuary; and

3. provide opportunities for wildlife viewing, fisheries enhancement, fishing, temporary safe anchorage, and other activities (AS 16.20.162(a)). Hunting, trapping, and mineral entry are prohibited in the Sanctuary.

The Sanctuary was expanded and the adjoining McNeil River State Game Refuge (Refuge) was created in 1991 (Figure 3). The Refuge was created for purposes similar to those of the Sanctuary. However, black bear and small game hunting and trapping are allowed in the Refuge, but hunting for brown bears is prohibited (AS 16.20.041). Additionally, human use in the Refuge is managed to maintain and enhance the unique brown bear-viewing opportunities within the adjoining Sanctuary. In 2019, the Alaska Department of Fish and Game (ADF&G) received 1,097 applications for McNeil River guided and standby bear-viewing permits (Griffin and Weiss 2020). Overall, 223 permits were issued and 200 permit holders visited the Sanctuary resulting in 1,215 visitor-use days and generating >$108,000 in permit income for ADF&G.

Clayton and Mendelsohn (1993) determined that visitors to the Sanctuary were willing to pay up to $500 (2019 dollars) in fees to visit this site.

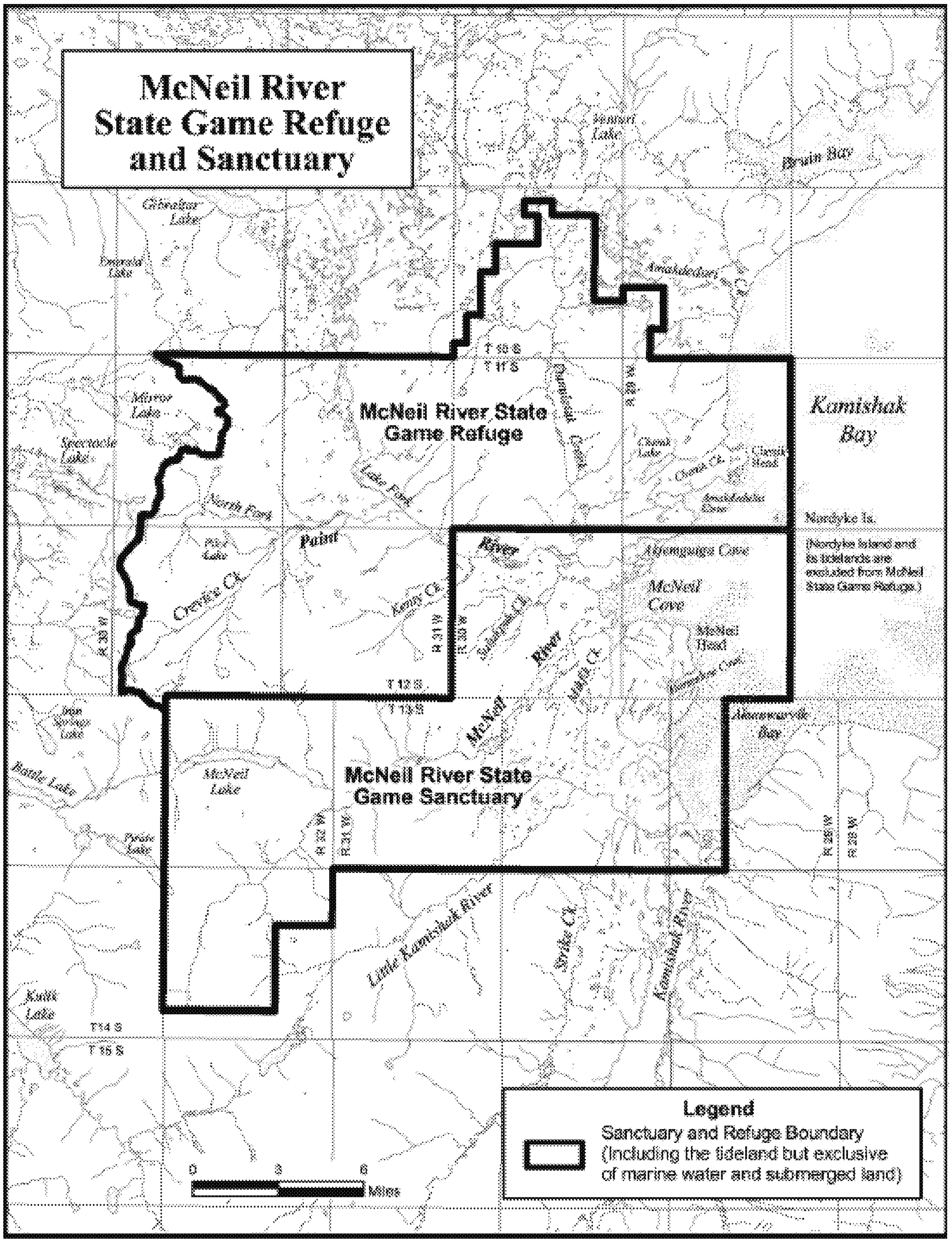

Figure 3. The McNeil River State Game Sanctuary and McNeil River State Game Refuge in Southwest Alaska (from Schempf and Meehan 2008).

The Sanctuary and the Refuge are approximately 1,005 km^2 (388 mi^2) in size (Griffin and Weiss 2020). These areas are included in a larger area of approximately 14,464 km^2 (5,585 mi^2) that includes Katmai National Park and the Kamishak Special Use Area (Alaska Department of Natural Resources 1990) in which brown bears are protected from hunting.

In 2017 the Pebble Limited Partnership submitted applications to the U.S. Army Corps of Engineers (USACE) for development of the Pebble Mine in Bristol Bay; including an alternative that places a road and a natural gas pipeline closer than 76 – 91 m (250 – 300 ft) and an industrial port facility within 3.2 km (2 mi) of the northern border of the Refuge. Policies within the Refuge and Sanctuary do not allow activities that would compromise the ecological integrity of the area (Schempf and Meehan 2008). This includes construction of new permanent roads, pipelines, utility lines, or docks, primarily to prevent disturbance to brown bears.

The Economics of Viewing Brown Bears in Southwest Alaska

While essentially all brown bears are managed at the population level, the brown bears at specific locations in Lake Clark National Park and Preserve, in Katmai National Park and Preserve, and at McNeil River are unique in that individual brown bears have specific importance to the continued success of the visitor experience that these areas provide.

Southwest Alaska residents and visitors were estimated to spend nearly $145,000,000 (2019 dollars) annually to view wildlife (ECONorthwest 2014). These expenditures generated more than an additional $133,000,000 in associated annual economic activity in Southwest Alaska (ECONorthwest 2014). A more specific economic analysis revealed that business activity in this area related to viewing brown bears resulted in approximately $34,500,000 (2019 dollars) in sales revenue, $10,000,000 in direct wages and benefits, and 490 jobs (Young and Little 2019).

Fay and Christensen (2012) provided an assessment of the economic significance of visitor spending associated with Katmai National Park and Preserve. Their assessment indicated that visitor spending supported approximately 390 jobs and approximately $56,700,000 (2019 dollars) in total output. Thomas et al. (2019) described a modelling framework used to calculate the statewide economic contributions associated with visitor spending related to Katmai National Park and Preserve and Lake Clark National Park and Preserve. They reported that visitor spending related to Katmai National Park and Preserve supported 707 jobs and approximately $83,000,000 (2019 dollars) in total economic output. Visitor spending related to Lake Clark National Park and Preserve supported 271 jobs and approximately $31,800,000 (2019 dollars) in total economic output (Thomas et al. 2019).

Pebble Project

The Pebble Limited Partnership is proposing to develop the Pebble copper-gold-molybdenum porphyry deposit (Pebble deposit) as a surface mine in Southwest Alaska near Iliamna Lake, approximately 322 km (200 mi) southwest of Anchorage and 97 km (60 mi) west of Cook Inlet

(Figure 4). The closest communities are the villages of Iliamna, Newhalen, and Nondalton, each approximately 27 km (17 mi) from the Pebble deposit. In 2018 the Pebble Limited Partnership submitted applications to the USACE for development of the Pebble Mine in the Bristol Bay watershed.

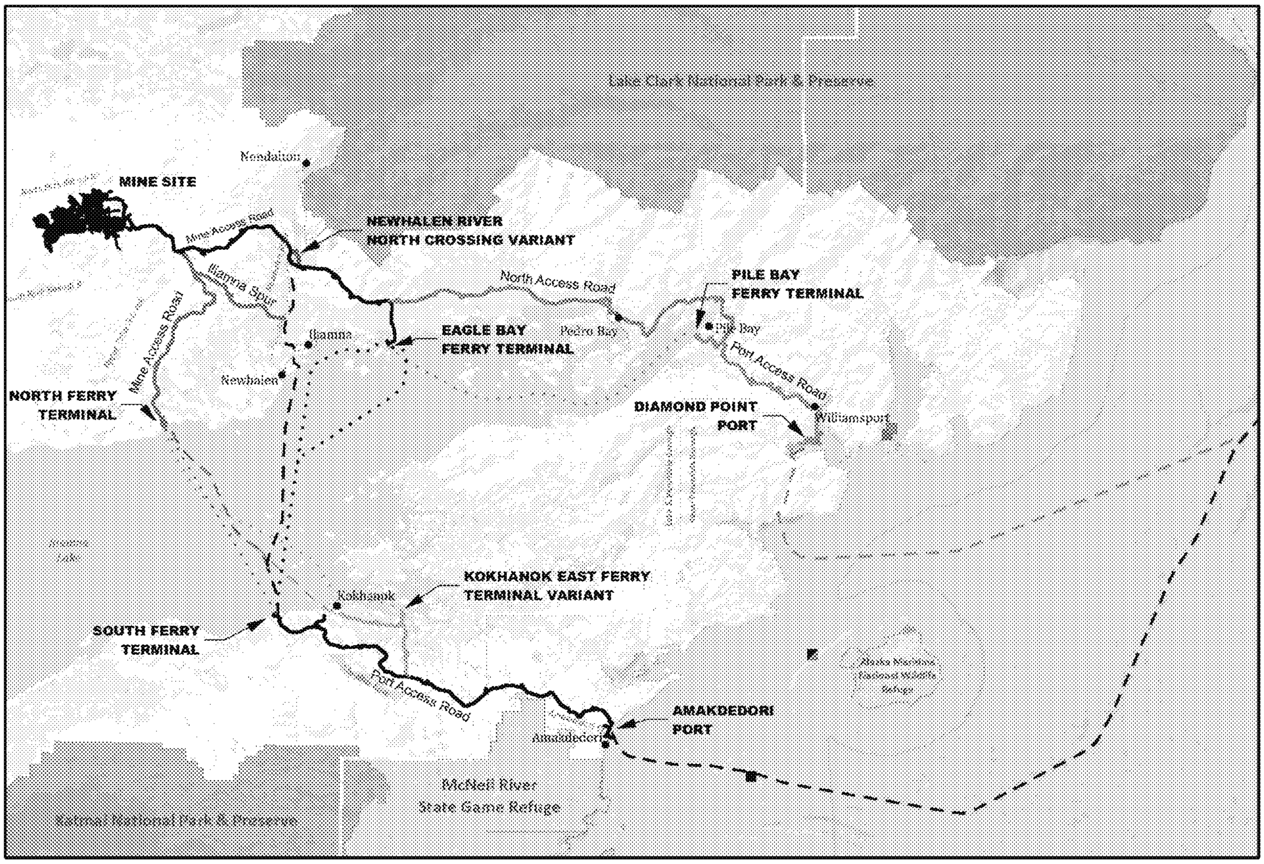

Figure 4. The Pebble Mine Project with the 3 action alternatives (US Army Corp of Engineers 2020:2-10).

Project Alternatives

Alternative 1a (South Road 1a) for the Project comprises 4 primary elements: (1) the mine site at the Pebble deposit location; (2) 1 port site in Kamishak Bay in Cook Inlet and 2 ferry terminals in Iliamna Lake; (3) a road corridor connecting the mine site, ferry terminals and port; and (4) a natural gas pipeline connecting to existing infrastructure on the Kenai Peninsula (Figure 4) (US Army Corp of Engineers 2020:2-4).

The proposed transportation corridor will connect the mine site to the proposed Amakdedori Port on Cook Inlet, and includes 2 main components: (1) a private, double lane, unpaved road extending 56 km (35 mi) south from the mine site to a ferry terminal at Eagle Bay on the north shore of Iliamna Lake; and (2) a private, double-lane, unpaved road extending 60 km (37 mi) southeast from the south ferry terminal west of Kokhanok to the Amakdedori Port on Kamishak

Bay. The port site will be located north of the Amakdedori Creek outflow into Kamishak Bay on the western shore of Cook Inlet. The port site will include shore-based and marine facilities for the transfer, shipment, and temporary storage of concentrate, freight, and fuel for the Project. This alternative would place a road and natural gas pipeline closer than 76 – 91 m (250 – 300 ft) and an industrial port facility within 3.2 km (2 mi) of the northern border of the McNeil River State Game Refuge.

Alternative 1 (South Road 1) for the Project comprises 4 primary elements: (1) the mine site at the Pebble deposit location; (2) 1 port site in Kamishak Bay in Cook Inlet and 2 ferry terminals in Iliamna Lake; (3) a road corridor connecting the mine site, ferry terminals and port; and (4) a natural gas pipeline connecting to existing infrastructure on the Kenai Peninsula (Figure 4) (US Army Corp of Engineers 2020:2-4 – 2-5).

The proposed transportation corridor will connect the mine site to the proposed Amakdedori Port on Cook Inlet, and includes 2 main components: (1) a private, double lane, unpaved road extending 56 km (35 mi) south from the mine site through the Upper Talarik Creek watershed to a ferry terminal on the north shore of Iliamna Lake; and (2) a private, double-lane, unpaved road extending 60 km (37 mi) southeast from the south ferry terminal west of Kokhanok to the Amakdedori Port on Kamishak Bay. The port site will be located north of the Amakdedori Creek outflow into Kamishak Bay on the western shore of Cook Inlet. The port site will include shore-based and marine facilities for the transfer, shipment, and temporary storage of concentrate, freight, and fuel for the Project. As with Alternative 1a, this alternative would also place a road and natural gas pipeline closer than 76 – 91 m (250 – 300 ft) and an industrial port facility within 3.2 km (2 mi) of the northern border of the McNeil River State Game Refuge.

Alternative 2 (North Road and Ferry) for the Project comprises 4 primary elements: (1) the mine site at the Pebble deposit location; (2) 1 port site at Diamond Point in Cook Inlet and 2 ferry terminals in Iliamna Lake; (3) a road corridor connecting the mine site, ferry terminals and port; and (4) a natural gas pipeline connecting to existing infrastructure on the Kenai Peninsula (Figure 4) (US Army Corp of Engineers 2020:2-5).

The proposed transportation corridor will connect the mine site to the proposed Diamond Point Port on Cook Inlet, and includes 2 main components: (1) a private, double lane, unpaved road extending 56 km (35 mi) south from the mine site to a ferry terminal at Eagle Bay on the north shore of Iliamna Lake; and (2) a private, double-lane road extending 29 km (18 mi) southeast from the south ferry terminal near Pile Bay to the Diamond Point Port on Iliamna Bay on the western shore of Cook Inlet.

Alternative 3 (North Road Only) for the Project comprises 4 primary elements: (1) the mine site at the Pebble deposit location; (2) 1 port site at Diamond Point in Cook; (3) a road corridor connecting the mine site and the port with a southern crossing of the Newhalen River; and (4) a natural gas pipeline connecting to existing infrastructure on the Kenai Peninsula (Figure 4) (US Army Corp of Engineers 2020:2-5).

The proposed transportation corridor will connect the mine site to the proposed Diamond Point Port on Cook Inlet. This includes a private, double lane, unpaved road extending 132 km (82 mi) south from the mine site to the Diamond Point Port on Iliamna Bay on the western shore of Cook Inlet.

Objective

After receiving, considering, and responding to >91,000 comments on the DEIS, the USACE released a Final Environmental Impact Statement (FEIS) on 24 July 2020 and is scheduled to release a Record of Decision in fall 2020.

The primary objective of this document is to review and evaluate the completeness of the USACE's response to comments submitted on the DEIS and response to issues identified on the potential impacts of the proposed Project (i.e., roads, natural gas pipelines, road corridors, and port facilities) on brown bears. Response to comments and issues identified concerning the potential impacts on brown bears associated with public viewing sites will be of particular interest. A secondary objective is to review response to comments and issues identified concerning general potential impacts of the Project on brown bears throughout Southwest Alaska.

Evaluation of the Potential Effects of the Project on Brown Bears

Issue: Analysis of Impact

The FEIS generally acknowledged the issues concerning brown bears that were raised in the scoping comments (US Army Corp of Engineers 2020) and, to an extent, described the potential impact of these issues on brown bears. The FEIS stated that beneficial and/or adverse effects of the Project were evaluated and described using *factors of analysis* (US Army Corp of Engineers 2020:4.1-1). But, the FEIS did not completely address the *factors of analysis*.

Evaluation of Overall Analysis of Impact in the FEIS

Almost universally, the FEIS does not provide an analysis of the impacts associated with the issues raised during the scoping process on brown bears that completely addressed the factors of analysis (4.1.1.2 Factors of Analysis – page 4.1-1) used to evaluate environmental consequences (i.e., magnitude or intensity, duration, geographic extent, potential to occur). This is in spite of the assurance on page 4.1-2 that:

> Each section in Chapter 4 describes analysis methodology and includes explanations of how each factor applies to that resource.

Magnitude or *intensity* of the potential effects to brown bears was presented in the FEIS as the area of land affected by the Project (page 4.23-1). This approach provides limited information associated with issues of concern identified for brown bears. Total area of land affected did not include such things as the quality of habitat for brown bears affected or the effect on movement patterns of brown bears. Magnitude of effect would be best described for brown bears as estimated changes in distribution, population density, and demographic factors. None of those were specifically addressed.

Duration of the effect of most issues of concern was generally adequately addressed (i.e., the effect would last the life of the Project).

Analysis of the *Geographic extent* of the effects was problematic for brown bears in that the analysis area for effects on terrestrial mammals (including brown bears) resulting from actions within the transportation corridors and at the ports was limited to a 4.8-km (3-mi) radius as defined in the FEIS (Table 3.23-1: page 3.23-3). Extensive comments on the DEIS addressed the concern that the geographic extent of the analysis area was not nearly large enough to adequately analyze the impact of the Project on brown bear populations. However, this issue was not considered or addressed in the FEIS. As stated in the FEIS, the analysis area was intended to encompass the full extent of impacts (permanent and temporary) that species may experience from the Project (page 3.23-1).

This approach is short-sighted and inadequate in that impacts to brown bears resulting from Project activities will affect the brown bear populations throughout their range in Southwest Alaska, well beyond the 4.8-km (3-mi) radius describing the analysis area. The contention in the FEIS is that it is not necessary that the analysis area for brown bears encompass the home ranges of brown bears. Rather, the FEIS asserts, brown bears that occur in and transit through the analysis area defined in the FEIS may be exposed to a variety of impacts from the Project, and will then move beyond/outside of the analysis area where the Project will not affect them (page 3.23-1). This ignores the fact that impacts on brown bears resulting from Project activities will affect the population throughout its entire range. High energetic demands and low population densities of large carnivores tend to result in wide-ranging behaviour, increasing the likelihood of interaction and conflict with a large number of brown bears and with humans associated with the Project (Ripple et al. 2014).

Landscape ecology suggests that a landscape is a species-specific construct arising from the spatial scales over which ecological processes occur (Solmundson et al. 2020). Species traits can be correlated with the scales of important effects and thus can identify relevant landscape extents for conservation. Brown bears are a landscape species because their habitat is not a specific vegetation type but rather an interspersion of various food resources and landscape features (Schoen 1990). The normal movements of brown bears are so extensive that a population's habitat must frequently be evaluated and managed on a landscape scale often exceeding 1,000s of km^2 (100s of mi^2). Glenn and Miller (1980) described the movement of brown bears on the

Alaska Peninsula and reported that brown bears moved greater distances per unit of time during spring than during other seasons of the year. Summer movements were restricted as brown bears concentrated along streams to feed on salmon. Dispersal away from streams began in late summer, eventually to den sites. The seasonal ranges of 30 adult females averaged 293 km^2 (113 mi^2) (and those of 4 adult males averaged 262 km^2 [101 mi^2]). The seasonal range of 5 subadult males and of 6 subadult females averaged 740 km^2 (286 mi^2) and 224 km^2 (87 mi^2), respectively. Collins et al. (2005) reported that 40 adult female brown bears in Southwest Alaska had home range sizes that ranged from 93-623 km^2 (36-240 mi^2) ($\overline{x}$ = 356 km^2 [137 mi^2]).

Mixed diets of meat (terrestrial and aquatic) and vegetation are optimal for mass gain in brown bears (Robbins et al. 2007). Terrestrial meat, salmon, and vegetation (e.g., berries) are often found in different areas throughout a brown bear's home range (Belant et al. 2010). Brown bears often require those mixed diets (Mangipane et al. 2018a). Subsequently, brown bears in homogenous landscapes such as those throughout the Project area use large home ranges to travel among areas containing necessary food resources (Mangipane et al. 2018b).

Clearly, any potential negative effects to brown bears that may occur in the vicinity of Project activities will have consequences for the brown bear population across a large area (i.e., significantly larger than the 4.8-km (3-mi) radius buffer on the transportation corridors that described the analysis area for brown bears in the FEIS). The ADF&G concurred with this finding in their comments on the Preliminary FEIS (Pebble_PFEIS_SOA_Comments_Enclosure-1.xlsx; ADF&G Worksheet, page 18 of 34).

Limited information is available to describe movement of brown bears specifically associated with viewing sites on the Alaska Peninsula. The anecdotal evidence that is available indicates that brown bears that frequent the Sanctuary and Refuge move extensively (Figure 5). This is also likely the case with brown bears that frequent sites in Lake Clark National Park and Preserve and in Katmai National Park and Preserve.

The FEIS also does not provide an analysis of the *likelihood* of recognized impacts on brown bears occurring if the Project were to be permitted and does not evaluate the *probability* of occurrence of recognized impacts based on results of analysis or modeling which would establish the degree of risk to brown bear populations of implementing the Project. This is despite the availability of techniques available to conduct such analyses (e.g., changes in probability of use by brown bears of areas influenced by the Project [Suring et al. 2006], probability of brown bears killed in defense of life or property [Suring and Del Frate 2002], changes in movement patterns of brown bears [Suring et al. 2017], food conditioning [Morehouse et al. 2016]).

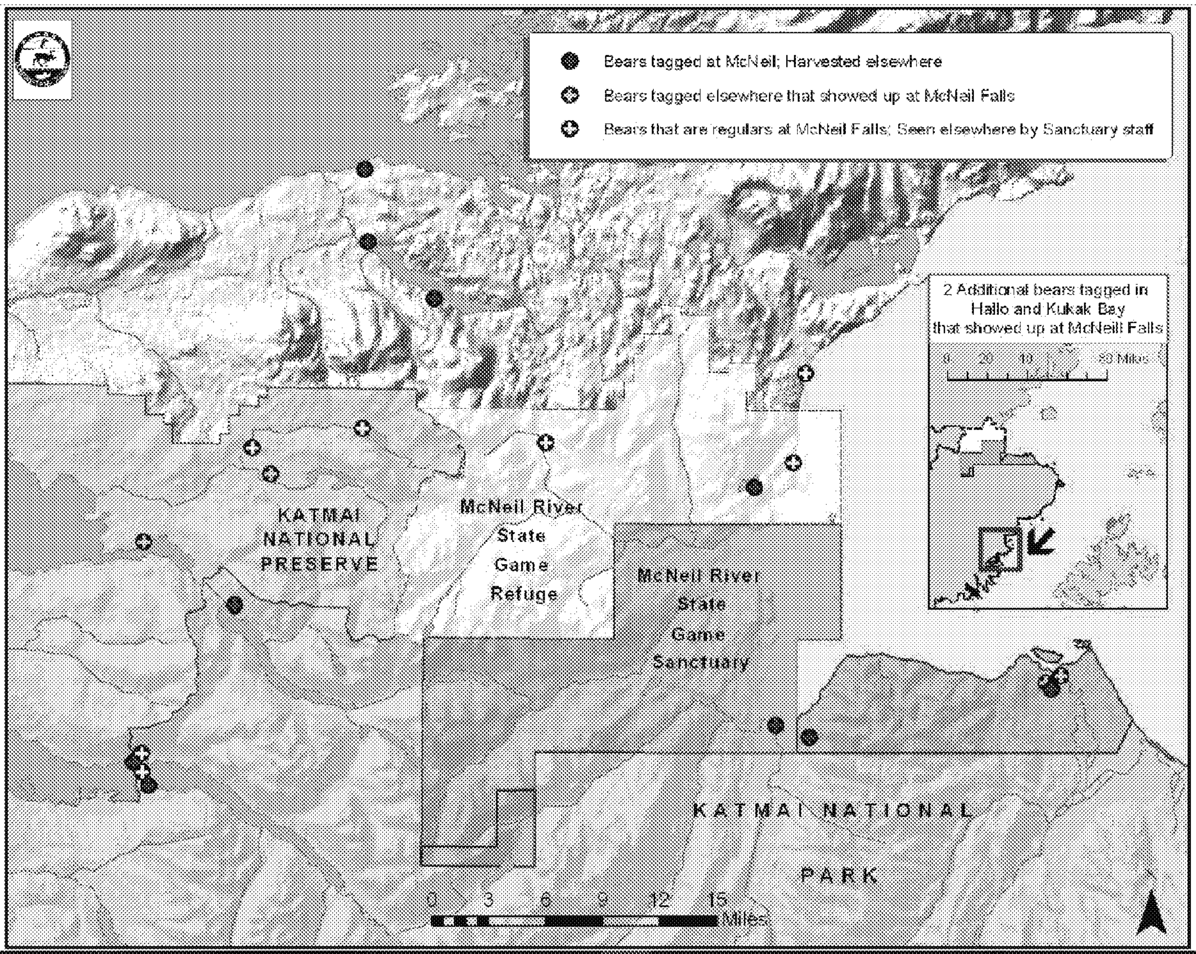

Figure 5. Movement of brown bears associated with the McNeil River State Game Sanctuary (from ADF&G).

Issue: Noise

Concern about the potential effects of noise generated by Project activities on brown bears was initially raised during the public scoping process (The Pebble Partnership 2019b; Section 3.4.2.5: page 11 and Section 3.4.3.4: page 17). Attempts by the USACE to address these concerns in the DEIS (pages 4.19-1, 4.19-3, 4.23-13, 4.23-18) were cursory and incomplete. The DEIS provided very little evaluation of the potential impact of noise generated by the Project on brown bears. The limited discussion ranged from brown bears are not "… protected by legislation with respect to noise" to conjecture that brown bears may not adapt to noise but that would not result in "…population-level impacts"; statements made without any supporting evidence.

Subsequent comments on the DEIS expressed additional concerns about the effects of increased noise generated by Project activities on brown bears; the lack of recognition of potential effects; and lack of specific efforts to address, minimize, and mitigate potential effects.

The USACE responded to these specific concerns by updating Section 4.23, Wildlife Values in the FEIS to include what they described as an expanded analysis of potential noise impacts to wildlife, with particular emphasis on brown bears from both temporary and permanent noise sources, including blasting from the pit and material sites. The FEIS acknowledges that all Project phases and components would result in elevated noise levels above current ambient levels of 35 A-weighted decibels (dBA) (page 4.23-15).

Evaluation of Analysis of Impact of Noise in the FEIS

The revised discussion on the potential impacts of noise on brown bears in the FEIS consisted of a statement that some individuals would experience disturbance because of noise and may move away from the sources of the noise disturbance (page 4.23-27). The FEIS also recognized that noise may have an effect on denning brown bears (page 4.23-23). However, this was not an expanded analysis of the potential impacts of noise on brown bears that was indicated. What is needed is a specific discussion of the potential impacts of specific sources of noise on brown bears, how these potential impacts will affect the use of habitats and movements of brown bear in the Project area, how these potential effects will be avoided or mitigated, and what the overall impact will be on brown bears in the Project area when effects cannot be avoided or mitigated.

One of the potential consequences of increased anthropogenic noise in the Project area acknowledged, but not discussed in any detail in the FEIS is disturbance of brown bears while denning. Brown bears are easily disturbed while hibernating and disturbances can have fitness costs, especially if brown bears are forced to relocate from a den when food resources are still unavailable (Swenson et al. 1997, Linnell et al. 2000, Evans et al. 2012). For example, Swenson et al. (1997) showed that 9% of their studied dens were abandoned as a result of disturbances, with brown bears forced to move up to 30 km (19 mi) before denning again, thus resulting in a significant fitness cost.

Anthropogenic noise is a widespread sensory pollutant, recognized as having potentially adverse effects on function, demography, and physiology of wild animals, including brown bears (Jerem and Mathews 2020). Studies of sound disturbance commonly examine how anthropogenic noise disrupts animal communications (Shannon et al. 2016). However, noise has also been found to negatively affect wildlife abundance and body condition (Ware et al. 2015, McClure et al. 2017). Animal responses to sound generally start at sound levels above 40 dB (Shannon et al. 2016). Archibald et al. (1987) measured sound levels around active timber-hauling sites and noted that brown bears avoided areas where noise exceeded 60 dB. The repercussions of long-term exposure to anthropogenic noise and long-term post-exposure effects of multiple noise-types and levels need to be addressed for the Project. Soundscape modelling approaches may be used as management tools to understand brown bear behaviour and responses to management activities (e.g., Brown et al. 2012, Parsons 2020). This level of analysis is needed if we are to successfully evaluate the potential effects of the Project on brown bears and subsequently manage the effects on brown bears of increasing exposure to anthropogenic noise associated with this Project.

Issue: Mortality of Brown Bears in Defense of Life or Property (DLP)

Concern about the potential of increased contact between brown bears that use the numerous viewing sites on the Alaska Peninsula and Project personnel resulting in direct brown bear mortality by humans through DLP kills was initially raised during the public scoping process (The Pebble Partnership 2019b; Section 3.4.3.4:page 17). Subsequent comments on the DEIS expressed additional concerns about the likelihood of brown bears being killed because of DLP by Project personnel.

Evaluation of Analysis of Impact of DLP Kills in the FEIS

The USACE responded to these specific concerns by updating Section 4.23, Wildlife Values in the FEIS to include reference to potential increased mortality from DLP kills (page 4.23-4, page 23-31, page 2.23-38, page 4.23-39, page 4.23-66, page 4.23-68). However, that discussion in the FEIS was limited to acknowledging that DLP kills would occur and potential mitigation of mortality from DLP kills (i.e., development and implementation of a Wildlife Interaction Plan [pages 4.23-11 – 12]). The potential effects of DLP kills on the population of brown bears were not evaluated in the FEIS. Additionally, the measures that will be included in the Wildlife Interaction Plan are inadequate to ensure that DLP kills of brown bears are minimized.

Food-conditioned brown bears and habituated brown bears do have increased vulnerability to mortality through DLP kills. This is true for food-conditioned brown bears because they will approach people to seek food and for habituated brown bears because they will tend to not avoid people during the brown bears' normal daily activities. The majority of recorded DLP kills in Alaska resulted from interactions unrelated to food-conditioning (Miller and Chihuly 1987, Miller and Tutterrow 1999, Suring and Del Frate 2002). Increasing densities of roads and trails and high-quality habitats were associated with an increased likelihood that brown bears would be killed in DLP on the Kenai Peninsula (Suring and Del Frate (2002).

Roads and trails increase human access to brown bear habitats and facilitate the use of adjacent lands, increasing the likelihood of encounters between humans and brown bears. The increased infrastructure and increased human population associated with this Project will likely result in increased encounters between people and brown bears. Many of these brown bears that are encountered may be habituated to humans based on the brown bears' previous experiences at viewing sites.

Habituated brown bears present at viewing sites in Lake Clark National Park and Preserve, Katmai National Park and Preserve, and the McNeil River State Game Sanctuary are likely to encounter infrastructure and personnel associated with the Project. These encounters may turn deadly for brown bears because of perceived risk on the part of humans. To mitigate the potential of human-brown bear encounters and subsequent DLP kills, roads developed for this Project should avoid high quality habitats for brown bears. Also, mitigation measures relative to use of Project roads and facilities should follow those implemented for the Greens Creek Mine in Southeast Alaska (Schoen and Beier 1990):

- Public access to Project roads and facilities should be prohibited and strictly enforced,
- Project personnel should not be allowed to possess and carry firearms while using Project roads or while at Project facilities,
- Project personnel should not be allowed off of the road bed or away from Project facilities except for Project activities (e.g., they should not be allowed to use the road or Project facilities to access hunting and other recreation activities), and
- When roads and other Project facilities are no longer necessary for Project purposes, they should be permanently removed or made impassable to motorized vehicles.

There is limited indication in the FEIS that DLP kills of brown bear in the Project area will be eliminated or minimized through mitigation practices. Analysis is lacking on what the potential magnitude of the DLP kill will be over the life of the Project and what impact that will have on the brown bear population.

Issue: Habituation and Food-conditioning

Concern about the potential of increased contact between brown bears that use viewing sites on the Alaska Peninsula and Project personnel resulting in food conditioning of brown bear was initially raised during the public scoping process (The Pebble Partnership 2019b; Section 3.4.3.4:page 17). Subsequent comments on the DEIS expressed additional concerns about the likelihood of brown bears becoming food-conditioned as a result of interactions with Project personnel and Project facilities.

This issue was addressed in the FEIS as follows (pages 4.23-38 – 39). Discussion in the FEIS states that brown bears that become habituated and frequent the mine site, ferry terminals, ports, or other Project locations, may become a safety risk. Some of these brown bears may experience hazing and other negative human interactions, and then travel to areas such as Katmai National Park and Preserve, Lake Clark National Park and Preserve, and McNeil River State Game Refuge and Sanctuary. Brown bears that are negatively habituated to the Project, or have become food conditioned, may then become a danger to the public at bear-viewing areas. Implementation of a Wildlife Interaction Plan would be anticipated to minimize the potential for conflict between wildlife and humans.

Evaluation of Analysis of Impact of Habituation and Food-conditioning in the FEIS

Habituation is a change in behavior in brown bears that results in familiarity with novel interactions with people without adverse consequences (Aumiller and Matt 1994, Suring and Barber 2010). When brown bears are repeatedly exposed to a neutral situation, such as a person observing them from a close distance, they conserve energy by muting their reaction. Consequently, habituation often is assumed to have occurred when brown bears tolerate people at close distances and vice versa. A large population of highly habituated brown bears has occurred at viewing sites in Southwest Alaska that perceive humans as neutral and not threatening and, therefore, less dangerous. As in other areas, habituated brown bears move closer to humans and exhibit fewer signs of stress than do nonhabituated brown bears (Herrero 1989). For example, highly habituated brown bears at the Sanctuary routinely approach humans to within 5-8 m (16-26 ft) before showing avoidance behavior (Aumiller and Matt 1994). A major point is that habituated brown bears often approach humans closely but do not pose a safety risk to people.

A large number of these habituated brown bears from viewing sites in Southwest Alaska are likely to occur in the vicinity of the Project's mine site, transportation corridor, and port sites where they may encounter nonhabituated people who would perceive these brown bears to be a threat. Mitigation measures will need to include the following best practices that are not discussed in the FEIS and need to be included in the Wildlife Interaction Plan.

- In-depth training so that Project personnel will be able to interpret the behavior of brown bears and recognize when a threat is actually occurring.
- Also, possession and access to firearms will need to be restricted so that use of deadly force is not the first recourse to the presence of a brown bear.
- Training in, and access to, non-lethal aversion techniques, such as bear deterrent spray, will need to be implemented, with penalties for non-compliance. Bear deterrent spray is an effective tool for defusing brown bear–human conflict in a nonlethal manner (Smith et al. 2008). Reliance on use of bear deterrent spray by Project personnel will promote human safety and conservation of brown bears while reliance on firearms would be much less effective (Smith et al. 2012).

Brown bears that are habituated to people at the Sanctuary and Refuge are not food-conditioned. However, these brown bears are likely to become food-conditioned during encounters with Project personnel and facilities, unless actions are taken to prevent this. Food-conditioning in brown bears occurs when they develop a learned association of humans with available food (Herrero 1985, Mattson 1990). Positive conditioning of brown bears to human-provided food sources occurs when either or both of two circumstances exist:

- brown bears have fed on human-provided food,
- brown bears learn to associate humans and/or human development as potential sources of food (Gilbert 1989).

Herrero (1985) has documented that food-conditioned bears are more likely to seek food from people, to damage property, and to be killed than non-food-conditioned bears. Wilder et al. (2007) analyzed 171 bear-human incidents over 24 years in Lake Clark National Park and Preserve. They found that brown bears received food as a result of encounters with humans in 46% of the incidents, and that brown bears were killed in 23% of the incidents. Food-conditioned bears have been found to be 3 to 4 times more likely to be killed by humans than non-food-conditioned bears (Mattson et al. 1992).

This is especially problematic because brown bears previously habituated to humans at viewing sites that become food-conditioned on the Project site will then return to the viewing sites and be more aggressive towards people. Brown bears habituated to people at viewing sites do not consider people to be a threat and will go about fishing (and other) activity, essentially ignoring any people present. Food-conditioned brown bears expect to obtain food from people or from developments/activities associated with people (e.g., waste disposal). While seeking expected food, these brown bears often become aggressive to people in the area. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Number 25).

Unfortunately, the most direct and most effective approach to dealing with food-conditioned brown bears is to have agency personnel kill them (Witmer and Whittaker 2001). To avoid these situations it will be necessary to implement the following best practice mitigation measures:

- have in-depth training on food-handling for all Project personnel so they understand and appreciate the seriousness of preventing food-conditioning in brown bears.
- organic waste should be disposed of daily through incineration that meets Alaska Department of Environmental Conservation standards for combustion residue (i.e., <5% unburned combustibles).

Also, whenever human-made items are in brown bear habitat they are susceptible to damage from brown bears. A brown bear will investigate, often by chewing, an item or structure that it has not previously encountered in that location (Herrero 1985). New signs and other structures are commonly damaged. Brown bears may also show interest in petroleum products, paint, and oils such as linseed (Katmai National Park and Preserve 2006). Precautions should be taken to exclude vehicles and construction and maintenance materials from brown bears (e.g., fenced storage areas). This is important to ensure that brown bears do not become perceived as nuisance animals that need to be killed or removed.

Mitigation of habituation and food-conditioning in the FEIS primarily relied on the development and implementation of a Wildlife Interaction Plan (page 4.23-12) and then only after habituation and food-conditioning became a problem. Measures that will be included in the Wildlife Interaction Plan are inadequate to ensure that DLP kills of brown bears are minimized. The FEIS does recognize that practices that minimize attractants and eliminate food rewards are needed on the Project area to ensure that brown bears do not become habituated or food-conditioned (page 4.23-13). However, how the practices that minimize attractants and eliminate food rewards will be designed, implemented, and evaluated is not specifically addressed. The FEIS stipulates that an incinerator will be constructed at the mine site for domestic waste handling (page 4.23-24, page 4.23-28). An incinerator will also need to be constructed at the port sites to ensure that brown bears in those areas do not have access to domestic waste. Also, the FEIS suggests that brown bears will be attracted to the landfill at the mine site and may become food-conditioning (page 4.23-28). It is critical that materials and items that may attract brown bears not be disposed of in the landfill.

Issue: Dens

Comments submitted in response to review of the DEIS questioned the effectiveness of actions proposed to avoid denning sites of brown bears in the Project area. Discussion of brown bear den sites within the area that may be affected by the Project cited a description of the findings of an aerial survey of den locations and an associated modeling exercise (Prichard 2018). Results indicated that brown bear dens were located at lower elevations, steeper slopes, higher topographic positional indices, higher ruggedness, more north and west-facing aspects, and more often in shrubs (Prichard 2018).

The FEIS noted that brown bears may avoid denning in areas adjacent to the transportation corridors, especially the port access roads during construction and subsequent use (page 4.23-33, page 4.23-60). The only mitigation mentioned is that there may be additional surveys of dens prior to construction (pages 4.23-34).

Evaluation of Analysis of Impact to Dens in the FEIS

Discussion of brown bear den sites within the area that may be affected by the Project was limited to a description of the findings of an aerial survey of den locations (Prichard 2018). However, previous work in Katmai National Park and Preserve indicated that the ability to detect dens through aerial surveys, given that dens were actually present, was about 34% (NPS 2013). With the potential for increased human activities in this area as a result of resource extraction and human access associated with the Project, gaining a fuller understanding of specific denning requirements will be essential for describing the potential effects of the Project on use of den sites and associated fitness of brown bears, as well as developing future management actions that do not jeopardize the brown bear population (Mangipane et al. 2018c).

Unlike most hibernators, brown bears are aroused easily while in dens and disturbances while denning can result in fitness costs if brown bears become active during this period (Pigeon et al. 2014). Denning brown bears have been reported to have increased heart rates associated with seismic exploration activities (Reynolds et al. 1983). Secure denning habitat is vital for future conservation of brown bear populations, as den-site disturbance can result in lower reproductive success (Swenson et al. 1997) and reduced survival of dependent young (Linnell et al. 2000) following den abandonment.

Adult male brown bears in Denali National Park and Preserve selected den sites in areas with abundant, high quality food available at den emergence (Libal et al. 2011). Risk of infanticide appeared to influence adult female den-site selection, with adult females selecting higher elevations and steeper slopes than adult males. So, den site selection can be complex within a population (Wilson and Schmidt 2015).

The work of Goldstein et al. (2010) indicated that brown bears on the Kenai Peninsula selected locations for den sites away from roads and trails. Schoen and Beier (1990) assessed the effect of the Green's Creek mine site development on Admiralty Island on denning bears. The mean distance brown bears denned from the mine site the first year of observation was 3.4 km (2.1 mi). They denned significantly farther from the mine site after construction was initiated ($\overline{x}$ = 11.7 km [7.3 mi]). These results indicate that there is likely to be an influence on denning behavior of brown bears as a result of construction and operations in the Project area and that influence may negatively affect the brown bear population. For example, Elfström et al. (2008), Elfström and Swenson (2009), Sahlén et al. (2011) and Hodder et al. (2014) documented avoidance of denning close to roads and areas with high levels of human activity.

Findings from in-depth studies should be used to develop guidelines to minimize human–brown bear interactions and the potential impacts of land-use activities on occupied and potential denning habitat for brown bears (Pigeon et al. 2014). Preserving high-quality habitat for denning can be accomplished through planning and management because brown bears prefer and avoid specific landscape and land cover features when selecting dens. However, the best approach to obtaining the specific information needed on brown bear denning habitat to accomplish that for this Project is through a focused study using a large sample of collared brown bears (e.g., Goldstein et al. 2010, Mangipane et al. 2018, Sorum et al. 2019). The results of such a study from Southwest Alaska were not available for analysis in the FEIS.

Given the complex nature of habitat selection by brown bears for denning and that den attributes potentially affect energy conservation in hibernating brown bears (Shiratsuru et al. 2020), a high quality map of denning habitat suitability should be generated from a large sample of collared brown bears. This would be a useful conservation tool to assist in the spatial and temporal planning of human activities in areas exhibiting high probability of den presence, particularly during the denning period (Faure et al. 2020).

Issue: Roads (and associated pipeline corridor)

Concern about the potential impact on brown bears of construction of Project roads and the associated pipeline corridors was initially raised during the public scoping process (The Pebble Partnership 2019b; Section 3.4.3.4:page 17). Subsequent comments on the DEIS expressed additional concerns about the likelihood of adverse effects of the Project road (and pipeline) on brown bears. The concerns for some impacts to brown bears of the Project road (and pipeline) were recognized in the FEIS (page 4.23-33, 4.23-35). Minimal mitigation practices were discussed including yielding right-of-way to wildlife including brown bears, removal of road-killed carcasses so they do not attract brown bears, and speed limits (page 4.23-12).

Discussion in the FEIS recognized that brown bears would avoid crossing the Project road because of the traffic density on the road (i.e., ranging from 36 vehicles per 24 h period in Alternative 3 (North Road Only), Concentrate Pipeline Variant to 140 vehicles per 24 h period in Alternatives 1a, 1, and 2, Summer-Only Ferry Operations Variants; Table 1). The FEIS recognized that the long-term management of roads in the Project area is an important factor for understanding potential long-term impacts on brown bears (page 4.23-34). The FEIS initially qualified that the impact would occur only in the local area, but then went on to recognize that impacts would occur across the landscape used by brown bears (page 4.23-34). Discussion in the FEIS also recognized that the port access roads may cause habitat avoidance, alter movement patterns, and become ecological traps for brown bears (page 4.23-32).

Table 1. Transportation corridor traffic volume by Project alternative (From Table 2-2, US Army Corp of Engineers 2020:2-151).

Alternative	Vehicles per 24 h period
Alternative 1a (South Road)	73
Summer-Only Ferry Operations Variant	143
Alternative 1 (South Road)	73
Summer-Only Ferry Operations Variant	143
Alternative 2 (North Road with Ferry)	73
Summer-Only Ferry Operations Variant	143
Alternative 3 (North Road Only)	73
Concentrate Pipeline Variant	36
Traffic level at which brown bears avoid crossing roads (Northrup et al. [2012])	**>20**

Evaluation of Analysis of Impact of Roads in the FEIS

The ability of animals to survive in a changing environment, such as areas impacted by humans, is determined to a large extent by the characteristics of their movements (Battin 2004). Which, in turn, influence their demographics and population dynamics (Allen and Singh 2016, de

Gabriel Hernando et al. 2020). Movements are subject to inter-individual variation and are influenced by various intrinsic and extrinsic factors, such as mortality risk (Fortin et al. 2005), habitat (Bélisle et al. 2001), and anthropogenic influences (Tucker et al. 2018). Human activity can change the timing of animal movements (Gaynor et al. 2018) and create movement barriers (e.g., road networks) that may result in the reduction of home range size (Fahrig 2007, Tucker et al. 2018).

Of the total human footprint, the cumulative direct and indirect effects of roads and the access they enable are among the most pressing threats to conservation efforts (Sanderson et al. 2002, Robinson et al. 2010, van der Marel et al. 2020). The resultant encroachment of road networks and related human activity detrimentally affects biological diversity on undeveloped landscapes (Crist et al. 2005, Watts et al. 2007, Frair et al. 2008). The evidence is clear in the published literature that motorized access into brown bear habitats can have significant negative consequences on brown bears (Proctor et al. 2018, 2019). Roads cause functional habitat loss, alter movement patterns, and can become ecological traps for wildlife (Northrup et al. 2012). Proctor et al. (2018, 2019) found that roads through their habitat impacted brown bears at the individual and population levels through effects on brown bears' habitat use, home range selection, movements, population fragmentation, survival, and reproductive success that ultimately were reflected in population density, trend, and conservation status. However, many of these negative effects of roads are likely to be a function of the human use of roads, not the road itself.

Suring et al (2006) showed that relative probability of use by female brown bears on the Kenai Peninsula declined as road densities increased. Other work showed that on the Kenai Peninsula the probability of brown bears being killed in DLP increased as the density of roads increased (Suring and Del Frate 2002). Schoen and Beier (1990) evaluated the immediate effect of road construction in association with development of the Green's Creek Mine on Admiralty Island in southeast Alaska on brown bears. Prior to road construction they counted 57 day beds within 60 m (200 ft) of either side of Zink Creek. A year after road construction along the creek, they counted 17 day beds in the same area. Because they tend to use large areas, large carnivores like bears are particularly susceptible to the effects of roads (Gucinski et al. 2001). Road construction and use has substantially reduced habitat effectiveness for brown bears in other areas (Boulanger and Stenhouse 2014). The analysis of Boulanger and Stenhouse (2014) demonstrated that road density affects both the direct demography and trend of brown bear populations and also introduces additional risk into reproduction and recruitment.

Access management, the limiting of road access, is often suggested as a means to reduce mortalities but requires detailed knowledge of the response of brown bears to road traffic (Northrup et al. 2012). Some habitat value may be maintained near roads if traffic and firearms are restricted during resource extraction and roads are closed to all use (including all-terrain vehicles) after resource extraction has been completed (Boone and Hunter 1996, Wielgus et al. 2002, Wielgus and Vernier 2003).

Motorized access management—where roads are fully closed or restricted to the motorized public but may remain accessible to short-term industry use—is an effective mitigation and should be integrated into land use and wildlife management activities, particularly where brown bear conservation is a priority (Proctor et al. 2018). Temporal closures (e.g., between 2000 and 0800 hours) have been used successfully as a conservation tool that increased habitat quality for brown bears (Whittington et al. 2019).

The FEIS concluded that the Project would not result in increased hunting pressure on brown bears (page M-11). However, if Project roads are not fully closed or restricted to the motorized public, significant portions of the brown bears' range would be much more accessible to hunters. This would likely result in increased harvest of brown bears by hunters and increased DLP kill of brown ears by ungulate hunters (McLellan and Shackleton 1988, McLellan 2015, Proctor et al. 2019).

Access management will help to reduce mortalities of brown bears in areas adjacent to roads. However, it does not address mortalities of brown bears resulting from collisions with Project vehicles on the road (as experienced at the Green's Creek mine on Admiralty Island [USDA Forest Service 2003]) or the fragmentation of habitat due to the reluctance of brown bears to cross roads when they are in service. Specifically, roads often form a barrier to movement (Proctor et al. 2005, 2012, 2015) or contribute to direct mortality from collisions with vehicles (Collins and Kays 2011). Road mortality can be detrimental for wide-ranging species with low population densities and reproductive rates (reviewed by Fahrig and Rytwinski 2009). Road mortality can be especially limiting for large carnivores, with demonstrated detrimental effects on brown bears (Waller and Servheen 2005).

Northrup et al. (2012) reported that brown bears avoided crossing roads receiving >20 vehicles per 24 h period. Project road alternatives are scheduled to have a truck density ranging from 36 to 156 vehicles per 24 h period (Table 1). This density does not include maintenance vehicles and administrative traffic. To maintain movement patterns of brown bears in the area, it will be necessary to describe movement corridors for brown bears, identify probable locations for brown bears to cross the road, and facilitate crossing activity (e.g., Suring et al. 2017). Exclusion fencing and wildlife overpasses and underpasses have been successfully used to facilitate the safe movement of animals across roads (Corlatti et al. 2008, Beckmann et al. 2012, Ford et al. 2017) and may be essential to maintain movements of brown bears in the Project area.

Mitigation of the effects of roads has unambiguous net benefits for the safety of people and wildlife (Sawaya et al. 2014, Gilhooly et al. 2019), particularly for mitigation that consists of exclusion fencing (to prevent animals from accessing the road) coupled with crossing structures (to facilitate their movement; Huijser et al. 2016, Rytwinski et al. 2016). This combination of mitigation works well if crossing structures are permeable and frequent enough in landscapes to support wildlife movement (Jaeger and Fahrig 2004).

The complexity of reducing the adverse ecological impacts of motorized access is significant (van der Marel et al. 2020). The impacts often extend into the landscape far beyond the motorized corridor itself (Forman 2000, Watts et al. 2007, Frair et al. 2008). The FEIS speculates that there may be adverse impacts of the transportation and pipeline corridors associated with the Project (e.g., page 4.23-35). However, the magnitude, extent, and likelihood of those impacts are not described. Methods and means to avoid those impacts are not described. And mitigation of impacts that cannot be avoided is not addressed. The resulting apparent assumptions in the FEIS that the population of brown bears in the analysis area is not expected to be adversely impacted by influences of the road and associated traffic to a measurable extent are not supported by data from the Project area or by other studies of brown bears in Alaska or elsewhere. The ADF&G concurred in their comments on the Preliminary FEIS that this contention in the FEIS was not supported by data from the Project area or by other studies of brown bears in Alaska or elsewhere (Pebble_PFEIS_SOA_Comments_Enclosure-1.xlsx; ADF&G Worksheet, page 7 of 34).

Management and conservation efforts for brown bears associated with roads and the pipeline corridor in the Project area should focus on maintaining the linkages between habitat patches, so that brown bear movement is not hindered by barriers and brown bears can maintain home ranges large enough to meet their biological requirements and avoid risks. However, the FEIS concluded without supporting, local data that it may not be reasonable to implement temporal road closures and install wildlife crossings along the corridor (page M-13). Although, the FEIS then went on to state that road closures may possibly be implemented (i.e., closure periods when brown bears are most likely to be traveling may be reasonable [page M-14]).

Issue: Cumulative Effects

Concerns were expressed in numerous comments on the DEIS that the cumulative effects section was too broad and did not adequately describe the potential cumulative effects of all past, present, and in particular, reasonably foreseeable actions on brown bears.

In response to this concern, the USACE's contention was that the discussion of cumulative effects in Section 4.23, Wildlife Values, was updated to include additional information on potential impacts to wildlife species (such as brown bears) associated with loss of habitat and behavioral change (including altered movement patterns) from the 78-year buildout scenario and additional mineral exploration activities. USACE also claimed that the updated discussion included a review of some pertinent literature on mining impacts on ecosystems affecting brown bears. The FEIS included a review of one publication (Johnson et al. 2005) that assessed the cumulative effects of mineral exploration and development on several focal species, including brown bear. However, the discussion following that review of cumulative effects associated with the Project in the FEIS did not specifically address brown bears. The potential effects that were identified in this discussion were not analyzed relative to the influence they may have on brown bear populations.

Under 4.23.8.2 Reasonably Foreseeable Future Actions, it is noted that brown bears may change their foraging areas and have increased mortality from new roads, and mortality from DLP (page 4.23-68). The following was also noted in the FEIS under the cumulative effects analysis: brown bears may avoid denning habitat, and Iniskin Bay has a large seasonal concentration of brown bears at the end of the bay, which would be directly impacted (Table 4.23-4; page 4.23-70, 71).

Evaluation of Analysis of Cumulative Effects in the FEIS

An effective analysis of the cumulative effects on brown bears would certainly include the specific combination of changes to the brown bears' environment that are caused by Project actions in combination with other past, present, and potential future human actions. What is included in the FEIS under cumulative effects for brown bears is a passing mention of general potential effects of the Project on brown bears. Cumulative effects are not addressed and are not analyzed. Understanding and managing the cumulative effects of land-use activities require multifaceted planning and management frameworks (Shackelford et al. 2017) which were not developed for the analysis of this Project. Many land-use planning efforts, including this FEIS, fail to adequately capture how the cumulative effects of human footprint impact migrating species or those with large home ranges that depend on the connectivity of unprotected areas for movement and foraging (Noss et al. 1996, Hauer et al. 2016, van der Marel et al. 2020).

Hallam et al. (2020) highlighted the importance of explicitly considering ecological relationships of species, spatial configuration of habitat, and disturbance when evaluating the impacts of landscape scenarios on a species, including its persistence. Guidance exists on performing an analysis of cumulative effects of a project like this on brown bears. Johnson et al. (2005:4) provided a synopsis of the potential individual effects that may cumulatively impact a population of brown bears.

- The construction of facilities, such as roads, trails, or buildings, and increased presence of humans, beyond some threshold, will result in a direct loss of habitats, or indirectly, following avoidance behavior of affected brown bears.
- Human facilities, especially roads, trails, pipelines and other linear developments, also can fragment and isolate habitats.
- In addition to a loss or reduction in the effectiveness of habitats, disturbance may result in response behaviors with negative social or physiological consequences.
- Disruption of breeding or rearing activities can reduce fecundity and recruitment.
- The nutritional or hormonal costs of avoiding or responding to a disturbance may have cumulative and important implications for individual fitness and population productivity.

- More directly, human access can increase mortality through non-monitored and controlled hunting, vehicle collisions, or the removal or destruction of problem brown bears.

Vypovska et al. (2017) addressed the following aspects in their assessment of the cumulative effects of extraction of natural gas on brown bears in British Columbia:

- Degradation, loss, and fragmentation of habitat
- Loss of habitat effectiveness
- Creation of barriers or filters to movements
- Impact to the reproductive potential of breeding females.

Mowat et al. (2018) used ALCES Online (Carlson et al. 2014, Magness et al. 2006), a computer model designed for comprehensive assessment of the cumulative effects of multiple land uses and natural disturbances to ecosystems, to evaluate the cumulative effects of resource development on brown bears in Elk Valley in British Columbia's East Kootenay region. They evaluated:

- Habitat availability considering human developments and roads
- Habitat connectivity
- Human-caused mortality
- Demographic trends

Suring et al. (1998) developed a model to analyze the effects of cumulative actions on brown bears on the Kenai Peninsula that incorporated many of these factors. Their model evaluated changes in quality of habitat for brown bears as a result of habitat modification (habitat submodel) and the reduction in the effectiveness of that habitat as a result of disturbance and mortality (human activities submodel).

The best approach to evaluation of cumulative effects involves focusing on a few key components of the human footprint and the development of multi-species approaches to the analysis (Shackelford et al. 2017, Toews et al. 2018). A similar analysis is needed for the Project to document and make clear the cumulative impacts all aspects of this Project will have on brown bears and other focal species. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Number 35).

Issue: Mitigation

Mitigation measures designed specifically for the conservation of brown bears are limited in the FEIS. A detailed brown bear interaction plan designed to minimize conflicts between brown bears and humans is intended to be incorporated into a Wildlife Interaction Plan that has not been completed (page 4.23-13). Specifics that are listed in the FEIS include (page 4.23-13 – 14):

- The use of bear-proof containers and bear-proof trash receptacles for food and garbage,
- Locations of brown bear dens newly discovered by Project personnel would be reported to ADF&G and a 0.8 km (0.5 mi) buffer placed on the newly identified den unless a non-mobile facility occurred within the buffer,
- Surveys may be conducted pre- and post-construction to locate denning areas of brown bears and to document changes in denning use due to project impacts,
- Mine workers would receive training on ethical behavior around brown bears.

The only additional specific references to brown bears in the Mitigation Chapter (5.0) of the FEIS are on page 5-11 where it suggests that a detailed interaction plan designed to minimize conflicts between brown bears and humans would be eventually be incorporated into a Wildlife Interaction Plan, page 5-12 where it suggests that road traffic would stop, if necessary, to allow passage of brown bears and that road-killed animals would be removed so they do not attract brown bears, and page 5-14 where it suggests that helicopters and fixed-wing airplanes should avoid flying directly overhead of bears and maximize lateral distance as quickly as possible.

The approach in the FEIS to mitigating adverse effects of the Project on wildlife, in general, consists of eventual development of a Wildlife Interaction Plan (page 5-10) that is intended to keep human-wildlife interactions to a manageable and acceptable level. The FEIS also refers to eventual development of a Wildlife Management Plan (page 5-66) that would presumably include monitoring to assess impacts of the Project on wildlife and assess the effectiveness of the limited mitigation measures described in the FEIS.

Evaluation of Mitigation in the FEIS

Brown bears have experienced drastic contractions in their distribution across their range due to direct loss of habitat, reduction in habitat effectiveness, and direct persecution (Ripple et al. 2014, McLellan et al. 2017). Survival of brown bears decreases in areas where humans and brown bears overlap, especially near roads and other developments (Falcucci et al. 2009, Schwartz et al. 2010a), even in unhunted populations (Boulanger and Stenhouse 2014, Nielsen et al. 2004). Conservation of brown bears under increasing densities of humans, roads, and other infrastructure requires substantial management and mitigation of human developments and activities.

Where people and wildlife, particularly brown bears, share the landscape, challenges arise (e.g., brown bears will avoid high-quality habitats that have a high risk of human-induced mortality [Lodberg-Holm et al. 2019]). There is a large amount of literature documenting human-wildlife conflicts and mitigation efforts across myriad landscapes (Morehouse et al. 2020). However, in-depth evaluations of the effectiveness of mitigation practices are limited (Eklund et al. 2017, Lozano et al. 2019). As human incursions into the Alaska wilderness increases and wildlife habitat and habitat effectiveness decreases, it is likely that human-carnivore conflicts will remain a persistent conservation challenge. Long-term coexistence of the Project and brown bears requires an ongoing multidisciplinary commitment to think creatively, test new ideas, and work collaboratively (Morehouse et al. 2020).

The Pebble Limited Partnership currently has the opportunity to address the conservation of brown bears using 2 separate conservation and mitigation strategies: (1) conservation and protection of existing source habitats and secure areas to impede habitat degradation and ecological disruption; and (2) direct mitigation of sites where risk of mortality and ecological disruption is high and manageable (Nielsen et al. 2006). It is apparent that risk of mortality and ecological disruption associated with the Project is high for individual brown bears and their population. Consequently, an integral part of managing and conserving brown bears during development and operation of the Project will be the development and full implementation of a comprehensive mitigation plan.

Mitigation planning will provide the means and opportunity to integrate conservation of ecological processes into the design and implementation of the Project. Therefore, it is critical that the complete mitigation and monitoring plans be developed and be available for review and evaluation by the public prior to approval of the Project. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Number 8).

A substantial component of the conservation and mitigation process should include describing and conserving movement corridors throughout the ecosystem including construction of road crossing structures where appropriate. This aspect will be critical to ensure that movement patterns of brown bears are maintained across the landscape (Clevenger et al. 2002).

Issue: Base-line Studies on Brown Bears

The base-line studies on brown bears performed by ABR (ABR, Inc. Environmental Research & Services 2011) for the Project were summarized in the section of the FEIS on Affected Environment (page 3.23-21). The stated objectives for the base-line studies were to:

- Provide adequate baseline information needed for the affected environment portion of National Environmental Policy (NEPA) documents.

    - This included assessing the seasonal distribution and abundance of brown bears through field surveys in the mine area and initial transportation corridor to provide background for impact analyses.

- Characterize the distribution and abundance of brown bears (ABR, Inc. Environmental Research & Services 2011:16.2-1).
    - This included determining distribution and abundance at biologically important times of the year, including estimates of population densities of brown bears.

Evaluation of Base-line Studies on Brown Bears in the FEIS

Habitat-value assessments were prepared for brown bear (ABR, Inc. Environmental Research & Services 2011:16.1-13 – 16.1-34). The assessments were based on sightings made during superficial aerials surveys (i.e., convenience surveys of Anderson 2001) and limited reviews of the scientific literature. The aerial surveys conducted to describe the distribution and habitat used by brown bears had serious limitations, many of which were acknowledged by the investigators (e.g., difficult observability, nonrepresentative sample [ABR, Inc. Environmental Research & Services 2011:16.1-8]). The description of habitat use by brown bears in their assessment, as reported in the literature, is adequate, but limited (i.e., all relevant Alaska-based studies are not included and recent work from other areas is often missing) (ABR, Inc. Environmental Research & Services 2011:16.1-16 – 16.1-21). As a result, the habitat-value assessments for brown bears in the vicinity of the Project provide a limited view of the use and values of habitats.

Understanding trends in population abundance is fundamental to wildlife management and can be critically important for conservation of at-risk species (Taylor et al. 2005, Kendall 2019). A population estimate was conducted for brown bears in May 2009 following procedures published and implemented by ADF&G (Becker and Quang 2009, Becker 2010). The methodology for these population estimates followed those developed by the ADF&G and is considered to be scientifically sound.

Considering the above, before development and implementation of the Project it is important to:

- Supplement current literature reviews on habitat-use patterns of brown bears with a more thorough examination of the available literature, including more recent literature.
- Prepare a more comprehensive synthesis of the literature to better establish the biological foundation for statements made in the literature reviews relative to habitat use in the project area.
- Complete periodic (e.g., every 3 years) population estimates for brown bears within the project area, using methods previously used, up to the point when development of the

mine begins. Ensure that data collection is robust enough to limit variability in the data and to result in estimates with high confidence of accuracy. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Number 10).

- Collect data on landscape-use patterns by brown bears and use those data to conduct analyses of habitat use in the project area (e.g., Resource Selection Functions [Ciarniello et al. 2007]). Data-based descriptions of habitat use by brown bears within the project area are currently not available and would provide an essential basis for evaluation of the effects of proposed mine development on brown bears. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Numbers 8, 18, 25, and 27).

Conclusions

Developing effective conservation strategies for wildlife, including brown bears, requires a full and empirical understanding of species' responses to human-mediated disturbances, alteration of habitats, and mortality (Frey et al. 2020). To date, extensive research has documented spatial and numerical responses of wildlife populations to anthropogenic disturbances and habitat change, such as population declines and local extirpations (Laliberte and Ripple 2004, Ceballos et al. 2017).

Brown bears associated with McNeil River Falls, Katmai National Park and Preserve, Lake Clark National Park and Preserve, and throughout Southwest Alaska are a resource that has high ecological, economic, and social value in Alaska, the Nation, and throughout the world (e.g. Walker and Aumiller 1993). Any impact on this resource through implementation of a large-scale mining project would have significant ramifications. The data and analysis provided in the Affected Environment and the Environmental Consequences sections of the FEIS are not adequate to fully understand and evaluate the effects of implementing a preferred alternative on brown bear habitat and population in this area.

Human activities associated with the Project are highly likely to displace brown bears from their preferred habitats and, therefore, limiting human activities spatially (Coleman et al. 2013) and temporally (Schwartz et al. 2010b) is crucial for the long-term conservation of brown bears in the area affected by the Project. Care should have been given in the FEIS to ensure that the focus on potential conflicts between conservation of brown bears and implementation of the Project is not just on mitigating social conflicts without addressing limiting human activities that are damaging to the brown bear population (Chapron and López-Bao 2020). Not doing so resulted in a risk that the analysis of the conservation-conflict kept conservation within the limits of human activities, instead of keeping human activities within the limits of the ecological relationships of brown bears (e.g., Gunther and Haroldson 2020).

Other major mine-development projects in Alaska (e.g., Greens Creek [Schoen and Beier 1990], Red Dog [Ballard et al. 1993]) and elsewhere (Johnson et al. 2005) were preceded by in-depth studies of the ecological relationships of brown bears in the project areas to provide information for subsequent conservation and management. Similar analyses on brown bears of habitat use patterns, denning ecology, movement patterns, and demographics (e.g., cub production, litter size, cub survival, adult survival, age of weaning, estimated age of first reproduction, inter birth interval, population size, sex and age ratios, annual natural mortality rate) should be completed prior to initiation of this Project. This will provide adequate base-line data to inform analyses of effects of the Project on brown bears which will, in turn, lead to development of a comprehensive mitigation strategy.

The findings of Hilderbrand et al. (2019) emphasized that local management decisions regarding brown bear populations and human activities should be informed by local data. Further, given the level of variation and uncertainty across populations, conservative management is warranted when local data are unavailable. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Number 19) and on the Preliminary FEIS (Pebble_PFEIS_SOA_Comments_Enclosure-1.xlsx; ADF&G Worksheet, page 16 of 34).

Morales-González et al. (2020) summarized the overall effects of the intrusion of human infrastructure into brown bear habitats as:

- increased disturbance,
- human-bear conflicts and human-caused mortality,
- behavioral alterations,
- reduced fitness and genetic diversity, and
- physiological alterations.

They went on to describe actions which promote brown bear-human coexistence in landscapes that are-modified by human activities. Among the key elements they identified were:

- reduction of human-induced mortality,
- use of scientific information for assessment of the effects of new infrastructures,
- improve education on waste management and bear deterrence methods,
- conserve and restore habitat connectivity,
- mitigate road effects and restrict off-road use,

- implement mitigation measures to minimize risk of encounters of brown bears and humans, and
- quantify empirically the effects of Project activities on the energetics and fitness of brown bears.

Efforts to protect areas of intact habitat for brown bears, maintain and enhance connectivity, and reduce human-caused mortality will tend to result in coexistence of brown bears with Project infrastructure and activities (Lamb et al. 2020). Specifically, wildlife corridors and mitigation passages are critical to the conservation of brown bears in the Project area, especially in ensuring that landscape use patterns of brown bears are maintained. Mitigation planning prior to project design will provide the means and opportunity to integrate ecological processes into the design and implementation of the Project. The ADF&G concurred with this finding in their comments on the Preliminary DEIS (ADF&G Conservation Comment Number 8) and on the Preliminary FEIS (Pebble_PFEIS_SOA_ Comments_Enclosure-1.xlsx; ADF&G Worksheet, page 9 of 34, ADF&G Worksheet, page 10 of 34). Also, upon initiation of the Project, a rigorous monitoring plan needs to be implemented to evaluate the accuracy of effects analyses and the effectiveness of the mitigation strategy to ensure the continued wellbeing and likely survival of these brown bears.

Recommendations

This review has illuminated the paucity of information regarding the ecological relationships of brown bears and the response of brown bears to anthropogenic disturbance and infrastructure in Southwest Alaska similar to that associated with the Project. The FEIS recognized this information need by responding positively to a proposal to implement analyses of habitat use and movements of brown bears to guide design and layout of Project features (page M-15). However, this recognized information need was not acted on and the development of the FEIS proceeded without this information.

Much of this information is needed to fully evaluate the potential effects of all aspects of the Project on brown bears. As a result, it is recommended that modelling analyses be undertaken during, or prior to, the permitting process of the Project to provide initial information needed to guide Project planning and implementation so that negative effects on brown bears can be addressed and minimized. To facilitate a timely application of this work, it is suggested that these modelling analyses be based on existing information on brown bears from Southwest Alaska and from other populations throughout Alaska.

The modeling effort should be complemented with a ≥3-year in-depth field study of brown bears in the vicinity of the selected alternative. The results of the field study would be used to evaluate and improve the previously-developed models. The revised models would then be used to guide project operation and the field study data would also establish a baseline for periodic monitoring throughout the Project.

Modeling Analyses

It is recommended that models be developed to assess the following aspects for brown bears and other focal species (i.e., moose [*Alces alces*], caribou [*Rangifer tarandus*], bald eagle [*Haliaeetus leucocephalus*]) on the Project landscape:

- Patterns of habitat use
- Selection of denning habitat for brown bears
- Risk of mortality
- Movement patterns and corridors
- Cumulative effects

Habitat and Risk Modelling

Patterns of habitat use, selection of denning habitat, and risk of mortality may be modelled for focal species using Bayesian Networks (BN). Beck and Suring (2009) identified and described the structure, uses, output, and operation of 40 habitat-relationships modeling frameworks to provide conceptual information useful for evaluation of how well specific frameworks achieve modeling objectives. Their assessment and the decision tree in Roloff et al. (2001) for selecting a wildlife habitat modeling approach lead to this recommendation for using Bayesian Networks (BNs) as a framework for developing and applying habitat quality and risk models for brown bear and other focal species in Southwest Alaska.

BN models using the Netica® (Norsys Software Corporation, Vancouver, British Columbia, Canada) modeling shell provide a structured tool for integrating information on ecological relationships for focal species, such as brown bears (Raphael et al. 2001). BNs depict probabilistic relations among causal variables and use Bayesian statistics to calculate probabilities of population presence in response to a given set of ecological conditions (Marcot 2006) and clearly display how ecological conditions influence wildlife populations (Marcot et al. 2001).

BNs are increasingly being used to model the response of wildlife species to a variety of environmental and ecological variables (e.g., Uusitalo 2007, Suring et al. 2011, Vilizzi et al. 2012, Gaines et al. 2017).

BNs provide a transparent tool in which complex relationships among variables can be clearly articulated, knowledge gaps identified, alternate scenarios compared, and the most important drivers for ecological responses determined (Marcot et al. 2006, McCann et al. 2006). The flexibility of BNs; their ability to cope with little and/or missing data; and the ease of incorporation of empirical data, expert opinion, or a combination of both make them well suited to a management assessment framework such as that needed for this Project (Nyberg et al. 2006). BNs have thus become an integral part of probability-based decision support tools (Marcot et al., 2006), which represent an effective means of synthesizing and applying ecological knowledge to management decisions (Beck and Suring 2009).

Potential Movement Corridors

Movement patterns and corridors of brown bears and other focal species may be modelled by applying the results of the BN modelling to further modelling of least-cost corridors linked with circuit theory analyses. Connectivity among habitat patches for brown bears and other focal species within a landscape depends on characteristics of the landscape (structural connectivity) and on aspects of the mobility of the animal (functional connectivity) (Adriaensen et al. 2003).

Least-cost modeling has been used to incorporate detailed information about the landscape as well as behavioral aspects of the animal to describe connectivity. Cost-weighted distance approaches to estimate movement corridors of animals represent the least accumulative cost required to move between a specified source and a specified destination (Beier et al. 2007). This method provides a flexible tool that provides insights into the relationship between animal movement and landscape characteristics. This method also identifies a set of near-optimal corridors for the landscape linkage network, with emphasis on corridors with the least cumulative cost-weighted distances (Chetkiewicz et al. 2006, Beier et al. 2008).

While these least-cost models implicitly assume animals have perfect knowledge of the landscape, current flow models applying circuit theory assume they do not have knowledge of potential movements more than 1 step ahead (Newman 2005). Real-world movement behavior of animals like brown bears may fall somewhere between these extremes (McRae et al. 2008, Richard and Armstrong 2010). While shortest-path methods have been used to develop empirical multivariate models of habitat connectivity (Schwartz et al. 2009, Richard and Armstrong 2010), predictions from current flow-based models are highly correlated with observed genetic distance in several plant and animal populations and may better reflect actual movement corridors (McRae et al. 2008, Lee-Yaw et al. 2009, Shirk et al. 2010).

Cumulative Effects

A Landscape Cumulative Effects Simulator (ALCES) may be used to structure and guide a cumulative effects analysis of the effects of the Project on brown bears and other focal species (e.g., Elk Valley Cumulative Effects Management Framework Working Group 2018). The ALCES toolkit delivers a holistic planning perspective by assessing cumulative effects of overlapping land uses and ecological processes to a diverse suite of environmental and socioeconomic variables (https://www.alces.ca/). Core functionality includes land-use simulation, geospatial data analysis and integration, and data visualization.

Field Study

It is recommended that the modelling analyses be accompanied with a concurrent in-depth field study of the brown bears associated with the selected alternative. Such a field study would be expected to span ≥3 years and would involve the capture and marking of a representative sample of brown bears with collars equipped with global positioning systems. The results of the field study would be used to verify and refine the models used in the modelling assessment of the ecological relationships of brown bears. The results would also serve as an ecological baseline for the brown bear population in subsequent monitoring activities.

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